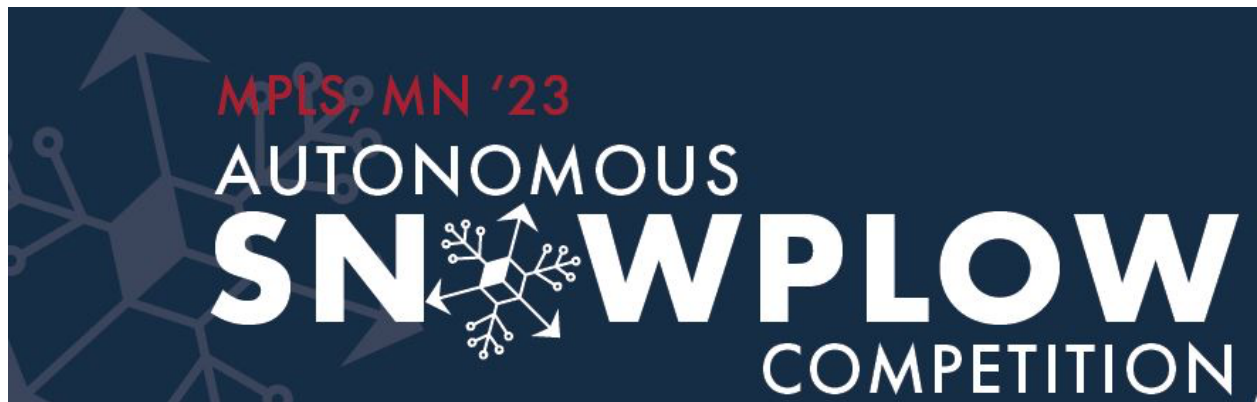


# **The Thirteenth Annual Autonomous Snowplow Competition**

## **Rulebook**



Revision 2023.1

Dunwoody College of Technology  
January 2023

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## SPONSORS

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# 1 Introduction

Dunwoody College of Technology, in collaboration with the Institute of Navigation, is pleased to announce the **Thirteenth Annual Autonomous Snowplow Competition (ASC)**. This competition is scheduled to be held at Dunwoody College of Technology in Minneapolis Minnesota during a week in January 2023.

The overall objective of the ASC is for groups to design and build an unmanned snowplow vehicle that will autonomously remove snow from pre-defined paths. The competition invites and challenges groups in the area of high-performance autonomous vehicle guidance, navigation, and control. The competition is also designed to encourage student interest in the areas of science, technology, engineering, and mathematics.

ASC Teams are required to build snowplow vehicles to autonomously remove snow from one snowfield within a set amount of time. The snowfield has a straight 'T'-shape, with a required entry of the vehicle from its garage onto the snow covered path. Teams can implement navigation-aiding systems surrounding the snowfield to aid the snowplow vehicle's navigation systems; however, there can be no direct human control of the vehicle during the plowing operation.

This event is a continuation of the previous competition year, and will lead to the dynamic events in January 2023. However, new Teams are eligible to join for the Thirteenth ASC, and are not required to have competed in the past Twelfth ASC.

The competition week will be composed of the following events:

- Thursday, 19 January 2023: ASC Teams will arrive in Minnesota, and as needed, drop off their snowplow vehicles at Dunwoody College
- Friday, 20 January 2023: Teams will qualify and demonstrate the operability and safety of their snowplow vehicles. ASC Teams will present their final snowplow vehicle designs to the ASC judges, to other Teams, and members of the public
- Saturday, 21 January 2023: Single-Vehicle Teams will compete on the single straight 'T'-shaped snowfield.

The theme of this Thirteenth ASC is *Precise Navigation and Coordination*.

The general concept for this in-person dynamic competition is for ASC Teams to *navigate, coordinate, and control their* robot for the overall goal of quickly and efficiently plowing snow off the snow field. The general purpose of each vehicle is to safely and accurately operate on a competition snow field in a fully autonomous mode.

ASC Teams will be judged throughout the design phase of the ASC and all competition week activities. In the design phase of the competition, teams will be evaluated on their snowplow vehicle concepts and their presentation skills during a Preliminary Design Review (PDR). This PDR will be held in December 2022, approximately three months after all the entry applications have been received. During the competition week, Teams have the opportunity to display and demonstrate their snowplow vehicle design through presentations, and will be judged on their vehicle's performance of removing snow from the competition snowfield.

A Final Qualification Review (FQR) Vehicle Demonstration and Safety Inspection will be conducted on Friday of the competition week. This FQR demonstration and inspection is conducted prior to the dynamic competition to ensure the snowplow vehicles satisfy the ASC design, operability, and safety requirements defined within this rulebook.

The Friday snowplow vehicle FQR and the Saturday dynamic competitions will be held at the snowplow competition field located at:

**Dunwoody College of Technology  
818 Dunwoody Blvd  
Minneapolis, MN 55403**

The Friday evening Welcome Reception and Student Poster Session event will be held at:

**Dunwoody College of Technology  
818 Dunwoody Blvd  
Minneapolis, MN 55403**

The event will include a social hour, where ASC Teams will have an opportunity to meet members of the other ASC Teams, the ASC Officials, the ASC Judges, and members of the public. Easels will be provided for Teams so they can present a poster or similar display of their snowplow vehicle design during this reception. ASC Teams should plan to have their vehicles on display at this event and plan to be available to answer questions about their vehicles by members of ASC Committee, ASC Judges, and general public.

The ASC will award prizes to ASC Teams within the competition. Teams that accumulate the greatest number of points during the PDR and competition week will be awarded cash prizes and trophies. The best student presentation during the Student Poster Session and Reception event during the competition week will be awarded the Golden Shovel Award. The ASC Team demonstrating the most enthusiasm and spirit throughout the competition will be awarded the Dr. Nattu Golden Smile Award.

In addition to the competition prizes and as funding is available, student ASC Teams may apply for travel grants to help offset their travel costs to the competition week.

## 2 General Information

### 2.1 Team Rules

#### Team Composition

The ASC welcomes groups comprised of high school, college, university undergraduate and graduate students, and members of the general public. All ASC Team members must be 18 years or older.

***All ASC Teams, including groups comprised of members of the general public, must have at least one student member.*** The student members of ASC Teams are entirely responsible for performing the PDR and Student Poster Presentations. Teams comprised primarily of high school, college, or university students should have a faculty advisor. Student ASC Teams are encouraged to invite students from all technical or engineering programs, as well as students from business programs, to design and promote the snowplow vehicle, solicit funding, and perform program management responsibilities.

Colleges, universities, and institutions are welcome to enter more than one Team into the ASC. Multiple Teams may compete using the same snowplow vehicle. However, no Team members may be in common between any competition Team. Furthermore, each Team's navigation aiding system must be designed independently and these unique designs must be clearly evident to the ASC Judges. Multiple ASC Teams from the same institution are required to independently prove their designs are unique. If multiple vehicles are entered from the same institution, then a different ASC Team must design each snowplow vehicle. Faculty advisors are allowed to advise more than one ASC Team. Each ASC Team must submit a separate ASC Application Form accompanied with the full entry fee.



## Team Sponsorship

ASC Teams are responsible for acquiring their own funding to design and build their snowplow vehicles. The competition organizers will work to gain sponsorship to provide partial funding for the competition week through travel grants; however, all ASC Teams are responsible for their own travel to the competition venue. Therefore, ASC Teams are encouraged to solicit sponsors to fund their entry.

Sponsors are allowed to provide funding or hardware for ASC Teams. Furthermore, Teams can place sponsor logos on their snowplow vehicle or navigation aiding sources, and can also place sponsor banners at the competition week's events.

## Competition Application Procedures

Each ASC Application Form must be accompanied by a non-refundable registration and entry fee of \$100.00 made payable to: **Dunwoody College of Technology**. For credit card payments, please contact [edaigle@dunwoody.edu](mailto:edaigle@dunwoody.edu).

The completed ASC Application Form, and the Application Fee are to be submitted to [edaigle@dunwoody.edu](mailto:edaigle@dunwoody.edu) as noted on the ASC Application Form, and must be received/postmarked no later than

**22 October 2022**

Please note that we highly recommend that all ASC Teams apply as early as possible, and begin the design and development of their snowplow vehicles long before this deadline.

Mail, fax, or email a copy of the completed, signed ASC Application to the following address:

**Dunwoody College of Technology**  
**ATTN: E.J. Daigle**  
**818 Dunwoody Blvd**  
**Minneapolis, MN 55403**

[edaigle@dunwoody.edu](mailto:edaigle@dunwoody.edu)  
Fax: +1-612-374-4128

## 2.2 Website

The main source for information about the ASC is via the competition website, which includes contact information for communication with the ASC Officials and Judges:

[www.autosnowplow.com](http://www.autosnowplow.com)

This website contains general information about the competition, competition documentation, past event information, current sponsors and sponsorship information, and competition contact information.

## 2.2 Timeline

The timeline for the Thirteenth ASC is provided in Table 1. The timeline is designed to give ASC Teams time to design and build their snowplow vehicles culminating with the competition week held at Dunwoody College of Technology on January 2023.

ASC Teams are encouraged to explore and enjoy the cities of Minneapolis and Saint Paul as much as time permits during the competition week.

**Table 1. Competition Timeline.\***

<b>Competition Item</b>	<b>Dates</b>	<b>Meeting or Location</b>
Applications Due	October 2022	N/A
Kickoff Meeting	November 2022	Videoconference
Preliminary Design Review	November/December 2022	Videoconference
Interim Status Meeting with Teams	December 2022	Videoconference
Interim Status Meeting with Teams	January 2023	Videoconference
FQR Vehicle Demonstration and Safety Inspection	20 January 2023	Dunwoody College
Student Poster Session and Welcome Reception	20 January 2023	Dunwoody College
Single Straight 'T'-Shaped Snow Path Competition	21 January 2023	Dunwoody College
Competition Awards Ceremony	21 January 2023	Dunwoody College

\*Note: All times listed are U.S. and Canadian Central Time Zone

## **2.3 Document Revision History**

The ASC Rulebook is provided as soon as the competition has been defined. ASC Officials reserve the right to update the Rulebook during the competition.

### ASC Rulebook Versions

- Version 2023.1
  - Initial Rulebook version released for the competition.

## 3 Autonomous Snowplow Contest

### 3.1 Overview

The objectives of the ASC are to design and operate an autonomous, unmanned snowplow vehicle to quickly and accurately clear snow from rectangular snowfields using the art and science of guidance, navigation, and control. This ASC includes the concepts of *Precise Navigation and Coordination*. Individual ASC Teams will take turns operating on the snowfield to clear snow, and their performance will be judged and scored. ASC Teams will compete against each other to earn the highest score.

ASC Teams are judged based upon their scores earned throughout the competition phases:

- 85% of the total score is based upon the dynamic plowing competitions; and
- 15% of the total score is based upon the presentations.

### 3.2 Rules and Regulations

#### Individual Team Snowplow Vehicle Design

The ASC is designed to challenge Teams in the areas of high-performance autonomous vehicle guidance, navigation, and control. In addition to these challenges, the ASC also provides Teams with interaction and feedback from industry experts throughout the entire design process from initial concept design through to the dynamic snowplow competition.

The ASC welcomes all innovative designs for a snowplow vehicle. However, as in any industry design of a concept vehicle, the vehicle must satisfy certain requirements for design, cost, and marketing purposes. Therefore, the ASC Officials have imposed several constraints on the snowplow vehicle design that would exist for vehicles used to remove snow from sidewalks or driveways, as well as to satisfy safety and practicality constraints:

- 1) Snowplow vehicles shall be autonomous and unmanned, and they shall not be remotely controlled during the competition. During the dynamic snowplow competitions, the snowplow vehicle may be moved from the snowplow staging area to the competition snowfields with human assistance. However, the snowplow vehicle must not receive human assistance while it is competing to remove snow from a snowfield. Any ASC Team whose snowplow vehicle receives human assistance while removing snow from a snowfield will be disqualified from that portion of the competition and receive zero points for that portion of the competition. *Remotely controlled* includes, but is not limited to: commands to modify or reset the snowplow vehicle's computers, commands to reinitialize the snowplow vehicle, commands to adjust a plowing route, etc.

- 2) For safety reasons, each snowplow vehicle has a speed limit of **2 m/s** that shall be strictly enforced.
- 3) The snowplow vehicle must be equipped with an Emergency Stop System (ESS), which consists of both a physical power-off switch and a wireless remote power-off switch that independently removes power from the vehicle's drive system. The physical, or manual, power-off switch must be easily identifiable and easily accessible to a person walking behind the snowplow vehicle. This switch must be located on the top surface of the vehicle and there shall not be any other protruding objects within a **30 cm** radius of the switch. This emergency stop switch shall be **red** in color and have a diameter of at least **40 mm**. The use of a remote power-off system that requires the reception of a wireless signal to *continue operating* is strongly recommend over a system that operates normally with no signal and *stops* when a signal is received. The wireless remote power-off switch shall remove power from the vehicle's drive system when the signal from the wireless control unit is lost or interrupted. The wireless remote power-off switch must have a minimum range of **50 m**. The snowplow vehicle shall cease operation and come to a complete stop within **3 meters** upon activation of either the physical or wireless remote power-off switch. The ESS shall not have a single point of failure, such that no single failure in the ESS or the vehicle shall inhibit the ESS from removing power from the vehicle's drive system. It is recommended that the ESS not process data through or require computer operation for the emergency stop. The ESS power cut-off capabilities of the snowplow vehicle must be demonstrated at the competition FQR Vehicle Demonstration and Safety Inspection. Snowplow vehicles that are determined to be unsafe or fail to meet the ESS requirements, as specified herein and as determined by the ASC Judges, shall not be allowed to participate in the competition.
- 4) The snowplow vehicle and any of its attachments must not exceed **2 m** in any dimension.
- 5) The plowing action may be completed using a solid plow blade and/or rotating brushes. Solid snow plow blades may be articulated, either up or down or rotated left and right, to adjust the blades angle to the snowfield path. Rotating brushes must operate such that no hard object (ice, pebble, etc.) can be ejected at a speed that will harm a person. No *snowblowing* – using an auger to ingest snow and chute to eject snow – implements are allowed.

- 6) The ASC will take place on an asphalt parking lot. Dunwoody College has added the following constraints on the design of the snowplow vehicle tires to preserve the pavement surface: the tires shall not be augmented with metal rivets, spikes, or chains to gain traction. Knobby, rubber winter tires are allowed. Other plastic or rubber augmentations to the tires are allowed. For example, metal wire coated with plastic or vinyl insulation may be wrapped around tires for traction. However, if the insulation jacket becomes damaged exposing the underlying wire, then the coated wire must be replaced prior to operating on the snowfield.
- 7) The snowplow vehicle must be self-powered and contain no power source external to the vehicle. Power shall either be by combustible fuel, batteries, or both. Other power sources must be cleared with the ASC Officials prior to the competition.
- 8) The plowing action shall be accomplished through direct contact with the ground surface.
- 9) The snowplow vehicle must be equipped with an electrical ground.

## Final Qualification Review Vehicle Demonstration and Safety Inspection

The Final Qualification Review (FQR) Vehicle Demonstration and Safety Inspection is an opportunity for ASC Teams to display their snowplow vehicles to the ASC Judges and demonstrate that their snowplow vehicles satisfy the design requirements and constraints. ASC Teams must demonstrate the following at the FQR:

- Their snowplow vehicle and navigation-aiding sources satisfy the ASC design constraints including vehicle dimensions, power, and electrical ground.
- The operability of both the physical power-off switch and remote power-off switch of the ESS for their snowplow vehicle.
- Their snowplow vehicle satisfies the ASC speed limit requirements by displaying their speed limit software, speed control hardware, and by running their snowplow vehicle at its maximum speed.
- Their snowplow vehicle can operate autonomously.

Should they fail any part of their initial FQR Vehicle Demonstration and Safety Inspection, ASC Teams are allowed to modify their snowplow vehicles or navigation-aiding sources and then resubmit their vehicle or aiding sources for review. Any physical modifications to the vehicle require a new review to verify that vehicle safety and other requirements are met. Once a snowplow vehicle and navigation-aiding sources have passed the FQR Vehicle Demonstration and Safety Inspection, ASC Teams are not allowed to modify their vehicle's speed limit software or speed control hardware. ASC Teams are allowed to modify their guidance, navigation, and control software any time during the competition subject to competition time limits.

The FQR Vehicle Demonstration and Safety Inspection will take place on Friday of the competition week at the competition field in Dunwoody's facility. The FQR Vehicle Demonstration and Safety Inspection will begin as listed in Table 1 with a schedule published by the ASC Officials in advance of the competition week. Each Team will be given an initial 15 minute time period during which the ASC Safety Judges will ensure that the snowplow vehicle and navigation-aiding sources satisfy the competition rules. If a Team initially does not pass the FQR Vehicle Demonstration and Safety Inspection, then the Team will be given as many inspections as needed until 5:00 pm on Friday evening to satisfy the ASC Safety Judges that the snowplow vehicle and navigation-aiding sources satisfy the competition rules. **The decisions of the ASC Judges are final.**

During the FQR Vehicle Demonstration and Safety Inspection period, all ASC Teams will be given the opportunity to view the competition snowfields and test their snowplow vehicles on a practice area at the competition site. ASC Teams may not test their vehicles within the dynamic competition area during the FQR Vehicle Demonstration and Safety Inspection period.

## Competition Plowing

- 1) The snowplow vehicles will be required to start autonomous operation in the Vehicle Starting Zone (Garage) and plow within the Snow Path areas.
- 2) The timer to begin each plowing run will be started from zero when the snowplow vehicle is within the Vehicle Starting Zone and the ASC Teams and ASC Safety Officials declare they are ready.
- 3) The Snow Path has buffer zones extending from their outer boundaries called the Vehicle Starting, Maneuvering, and Plowed Snow Zones. A snowplow vehicle must stay within these boundaries at all times once it enters the snowfield and is clearing snow from the Snow Path.
- 4) If any part of the snowplow vehicle extends outside the prescribed Vehicle Starting, Maneuvering, or Plowed Snow Zones, the ESS power-off switch shall be activated, a boundary infraction will be declared, and the vehicle must be moved back into the nearest plowed square-meter section of the Snow Path before a plowing run may be resumed. A penalty will be assessed when repositioning the snowplow vehicle for this boundary infraction as detailed in the scoring section below.
- 5) Teams are permitted restarts of their snowplow vehicles during each competition run. The snowplow vehicle must be repositioned back into the Vehicle Starting Zone for a restart. If an ASC Team chooses to restart, a penalty will be assessed. Note: the 20 minute clock does not stop when making decisions to restart or to reposition the vehicle.
- 6) Teams have a maximum of 20 minutes to clear snow from the Snow Path. The 20 minutes refers to the total plowing time allowed, and it includes the initial navigation-aiding sources set up, the initial competition plowing run, and possible plowing run restarts.
- 7) Team members, snowplow vehicles, or navigation-aiding sources may not touch any snow in the Snow Path prior to beginning a competition plowing run.
- 8) The snowplow vehicle should be designed to operate in any weather condition. In the event of severe weather, the competition may be postponed. The decision to postpone an event shall be made by the ASC Officials.



- 9) The snowplow vehicle may be equipped with **eye-safe (Class 1)** lasers. However, the lasers must be affixed to the snowplow vehicle and pointed towards the ground, with an angle at or below the local horizontal plane of the laser device. If lasers are used on the snowplow vehicle, then the laser harness and mounting to the vehicle must be displayed during the FQR Vehicle Demonstration and Safety Inspection. If requested by ASC Officials, a Team is obligated to provide proof the laser complies with Class 1 regulations (a certification sticker is sufficient).
  
- 10) Teams may place multiple navigation-aiding sources surrounding the Snow Path, but the sources must remain within the Maneuvering Zones and/or Plowed Snow Zones. These navigation-aiding sources must be stationary following their placement within the competition area.
  
- 11) Teams that choose to place navigation-aiding sources surrounding the Snow Path must begin their competition run with all aiding sources and Team members who are placing the aiding sources located within the Team and Navigation Aids Starting Zone prior to the start of their plowing run. Once the timer starts for the Team's plowing run, the Team members may move out of the Team and Navigation Aids Starting Zone and place their navigation-aiding sources around the Snow Path. A maximum of six Team members are allowed in the Team and Navigation Aids Starting Zone at the start of their run and for placement of the navigation-aiding sources. The placement of these aiding sources and any associated field surveys must be completed within the 20-minute allotted competition time. **NOTE: For the Thirteenth Annual ASC in-person event, this navigation-aiding source placement requirement will be relaxed for safety, such that each Team will be able to set up their navigation-aiding sources prior to their competition plowing run.**
  
- 12) A secondary navigation-aiding source zone will be provided to Teams for placement of remote navigation aids requiring longer set up time (e.g. differential GPS stations). This secondary navigation-aiding source zone will be located on the competition event site, but not directly within the snowfield boundaries. Teams cannot be assured of direct line of sight between this zone and a competition field, as this zone may be blocked by competition structures, competition volunteers, other competitors, or other aids. Set up for these remote navigation-aiding sources will not count towards the 20-minute allotted competition time.
  
- 13) The navigation-aiding sources may be actively emitting signals (e.g. radio, ultrasonic). If active, these navigation-aiding sources must be self-powered.

- 14) The ESS must be operational and active anytime the snowplow vehicle is in operation at or near the site of the competition.
- 15) Neither the snowplow vehicle nor the navigation-aiding sources may expel any fluids or objects of any kind within the snowfield competition boundaries. This ensures the road surface and snowfield conditions will remain identical for all Teams. Snowplow vehicle plow blades may not be heated, as this will cause plow snow to melt and act as an expelled liquid.
- 16) At the end of a competition plowing run, the snowplow vehicle must autonomously return and park within the Vehicle Starting Zone (Garage) on the snowfield. A penalty will be assessed if no portion of the snowplow vehicle is parked within this zone. The snowplow vehicle must remain within the snowfield boundaries as it returns to the Vehicle Starting Zone (Garage).
- 17) No ASC Team member, snowplow vehicle, or navigation-aiding source is allowed on the competition field after hours of operation, as posted by ASC Officials. This limitation is for safety and insurance reasons.

## Competition Procedures

Prior to a competition run, ASC Team members may move their snowplow vehicle directly into the Vehicle Starting Zone (Garage) on the competition snowfield, with the assistance of ASC Safety Officials. Teams can use the vehicle's power supply to maneuver their vehicle into the Vehicle Starting Zone. The vehicle can be turned off (unpowered) until the competition run officially begins, unless necessary for vehicle operation (e.g. provide heat to systems, keep navigation aids active). If the vehicle is turned on, then Teams must have their ESS system active to ensure the vehicle can be turned off immediately by an ASC Safety Official as necessary. Teams should notify ASC Safety Officials of their intent of powered operation prior to starting a competition run.

For those ASC Teams who place navigation-aiding sources around the snowfield prior to their competition run, Team members and their navigation-aiding sources must move into the Team and Navigation Aids Starting Zone and remain there until the run begins.

Each ASC Team is given a total of 20 minutes for their entire snowfield competition run. An ASC Team's run commences upon notification by the ASC Marshal. Snowplow vehicles can then be powered on (started) and ASC Team members can leave the Team and Navigation Aids Starting Zone and relocate their navigation-aiding sources within the Maneuvering Zones and/or the Plowed Snow Zones as required by the Team's design. Teams may initiate plowing operation at any time during their allotted 20 minutes to enable their snowplow vehicle to clear snow from the Snow Path.

Once an ASC Team's 20 minute plowing window is completed, the Team must move their snowplow vehicle and navigation-aiding sources back to the staging area. The ASC Judges will then assess the performance of the snowplow vehicle on the Snow Path, and the ASC Snow Pit Crew will prepare the Snow Path for the next ASC Team.

The ASC Marshal will oversee the snowplow vehicle competition schedule to ensure that the ASC events begin and end as scheduled.

Before an ASC Team turns on their snowplow vehicle within the competition snowfield, the Team must show the ASC Safety Official the operation of the remote power-off switch. A single member of the ASC Team will then maintain control and operation of the remote power-off switch. Along with an ASC Safety Official, this single member will remain outside but adjacent to the snowfield boundaries while a Team's snowplow vehicle is clearing snow from a Snow Path to operate the power-off switch or declare a restart. After a boundary zone infraction, a power shut down, or a declared restart, the remaining ASC Team members are allowed within the snowfield boundaries to assist with repositioning the vehicle to either the nearest plowed square-meter section of the Snow Path or back to the Vehicle Starting Zone. ASC Team members must minimize the amount of uncleared snow disturbed while repositioning their vehicle at the direction of the ASC Marshal. The ASC Safety Officials have the authority to engage either the physical power-off switch or remote power-off switch if the snowplow vehicle should travel outside the Vehicle Starting, Maneuvering, or Plowed Snow Zones. The decisions of the ASC Marshal and Safety Officials are final.

### **3.3 Snowfield Specification**

The ASC will take place in the parking lot at Dunwoody College of Technology, located at 818 Dunwoody Blvd. Minneapolis, MN.

The parking lot is a standard asphalt surface. ASC Officials will make every attempt to ensure that the snowfield paths are evenly constructed and fair for all ASC Teams. This venue is located in an urban environment with tall city buildings directly to the east of the campus.

The Thirteenth ASC has one competition snowfield, which include a **single straight 'T'-shaped** path, shown in Figure 1. The dimensions of the Snow Path as well as the Vehicle Starting, Team and Navigation Aids Starting, Maneuvering, and Plowed Snow Zones are provided in this figure.

The **single straight 'T'-shaped** path, Figure 1, will be solely used for the ASC event. Only a single vehicle will operate and compete on this course.

For the Snow Path, the snow depth will vary between **5.0 to 15.0 cm**. The decision of the snow depth variation is strictly up to the ASC Marshal's and Judge's discretion and will be implemented as part of the competition day setup. ASC Teams should anticipate this variation during their snowplow vehicle design and development. The ASC Officials will make every effort to ensure that the snowfield paths have the same total quantity of snow for each ASC Team, but the snowfield path depth and the snow consistency cannot be guaranteed to be exactly the same for each ASC Team.

The external boundaries of the Vehicle Starting, Maneuvering, and Plowed Snow Zones will be marked with PVC pipe, wood strips, metal bars, web strapping, or chalk markings on paver or asphalt pavement. These boundaries and zone markings will be obvious to ASC Team members, Officials, and the viewing public.

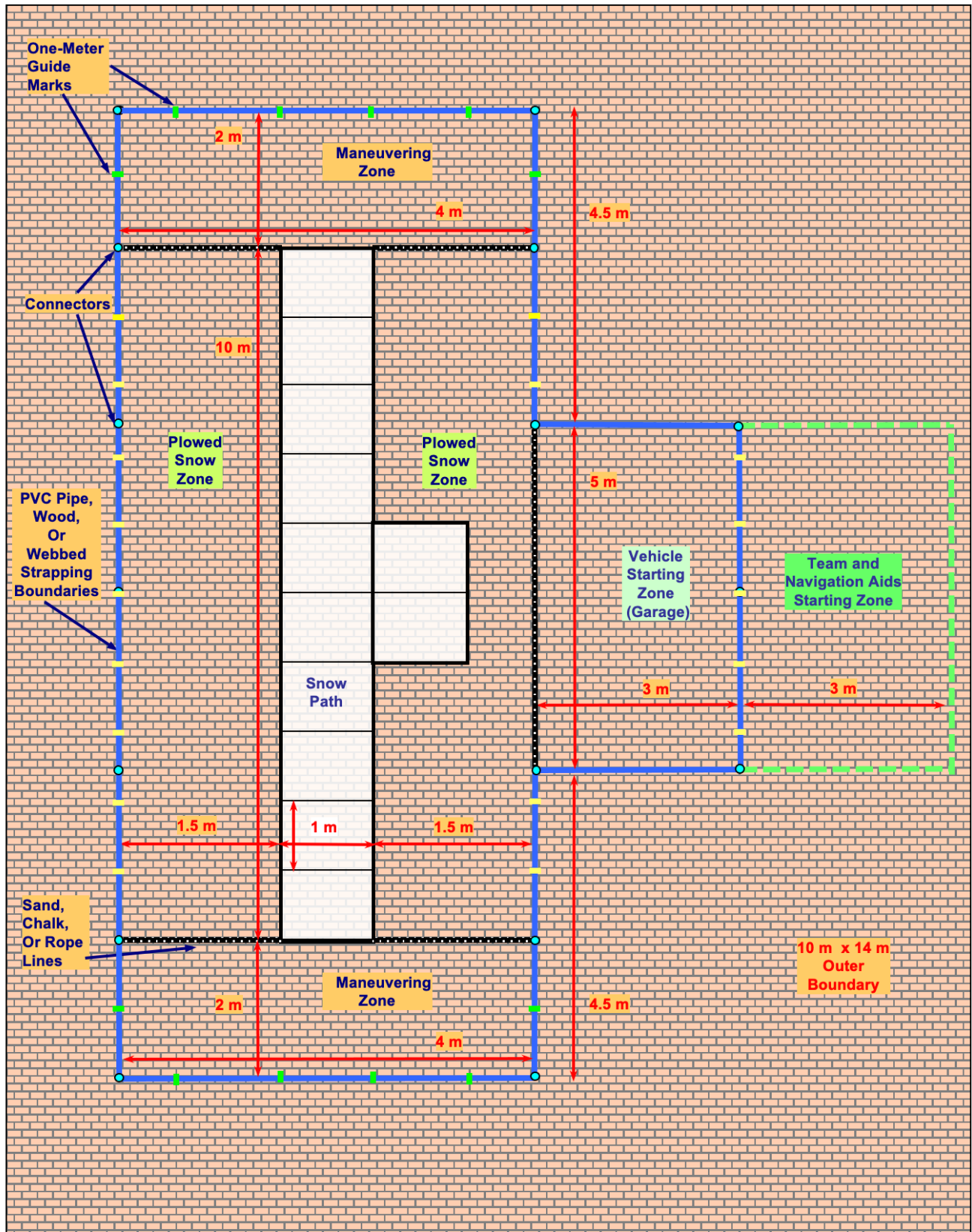


Figure 1. Single 'T'-shaped competition path snowfield diagram.

## Simulated Posts

Many house driveways have adjacent trees, and city sidewalks typically have parking meters. Some of these objects are located near but do not interfere with a snowplow vehicle when plowing a path or driveway. Other objects that are located on a sidewalk or driveway will interfere with the snowplow vehicle's path, and must be avoided by a snowplow vehicle.

To simulate fixed objects within the competition snowfield, two fixed posts, approximately **1.5 m high by 0.2 m wide**, will be placed within the boundaries of the competition field during both dynamic competition runs. These fixed posts will be included within the single 'T'-shaped snowfield. Random locations for these posts for each ASC Team run will be chosen by the ASC Marshal and Judges. The placement of these fixed posts will occur immediately prior to a Team's 20-minute competition run.

The first fixed post will be placed directly within the Snow Path. The 1-m<sup>2</sup> section in which the first fixed post is placed will not have any snow, so it does not need to be plowed by the snowplow vehicle. The second fixed post will be placed within the Maneuvering or Plowed Snow Zones outside of the Snow Path.

The fixed posts are considered part of the competition snowfield and no objects, such as navigation aids, may be physically attached to these posts by the ASC Teams during their plowing run.

Snowplow vehicles must be designed to avoid each fixed post during their operation. ASC Teams will receive a penalty for hitting, moving, or toppling over the post during their run. Moved or fallen snow from the snowplow vehicle is allowed to touch either post, and no points for hitting a post will be deducted if only snow (and no part of the vehicle) touches or remains on the post and does not move the post from its original location on the snowfield.

## Competition Scoring

ASC events and scoring methods are provided in this section.

**Table 2. Single-Vehicle Competition Events.**

Preliminary Design Review	5%
Final Student Poster Presentation/Design Review	10%
Snowplow Competition: Single 'T'-Shaped Snow Path	85%
<b>Total Competition Points</b>	<b>100%</b>

**The scores awarded by ASC Judges in all phases of the snowplow competition are final. Competitors must be aware that all decisions by the ASC Judges are final.**

## Technical Presentation Scoring

ASC Teams are required to present their snowplow vehicle designs at virtual and in-person presentations at the competition's two events of the Preliminary Design Review and the Student Poster Presentation Design Review.

The PDR presentation slides are due as shown in the ASC Timeline in Table 1. The entire PDR presentation must be delivered by the student members of the ASC team and will be conducted either using a video- or tele-conference. The PDR presentations will be attended only by ASC Judges, and any submitted materials will be held in confidence by the ASC Officials and Judges.

The Student Poster Presentations of the ASC Teams will be scheduled for Friday evening of the competition week, as shown in the ASC Timeline in Table 1. The Student Posters are due at the time of the presentation event. Teams are strongly encouraged to produce original presentation work each year, as ASC Judges will reduce scores for non-original work. The Student Poster Presentations must be delivered by student members of the ASC Team.

The Student Poster Session and Reception will be attended by the ASC Officials and Judges and are open to other ASC Teams, as well as the general public. Teams should bring posters or displays describing their snowplow vehicle designs and operation for show prior to the presentations, as ASC Judges and the audience will review these posters when meeting the Teams during the social hour. This Team and Judge interaction can often improve a Team's score.

The PDR and Student Poster Presentations scores will be based on the following scoring system:

**Table 4. Presentation Scoring System**

Technical Assessment and Quality of Presentation Poster	80%
Ability to Engage Audience and Answer Questions	20%
<b>TOTAL Points</b>	<b>100%</b>

Specific items that Judges would expect to be included as part of the Presentation will be listed and submitted to ASC Teams. Generally, the Presentation should include:

- Snow Vehicle Design Concept
- Navigation Sensors and Methods
- Guidance and Control Techniques
- Manufacturing Feasibility and Maintenance Characteristics
- Animation/Video/Simulation of Vehicle Operation on Snowfields
- Anticipated Performance  
(e.g., Time To Clear Snow, Vehicle Design Benefits)

## Plowing Competition Scoring

During the dynamic snowplow competition, ASC Teams will compete using their snowplow vehicles to clear snow from the snowfield paths. Snow is considered cleared from a snowfield path if the vehicle plows the snow out of the Snow Path into the Plowed Snow Zones. An ASC Team's vehicle performance in clearing snow from a Snow Path will be evaluated and assessed by a distinguished panel of ASC Judges, who will determine the percentage of the path cleared of snow within each 1-m<sup>2</sup> section of the snowfield path. A penalty will be assessed for obstacles hit, restarts taken or the inability of the vehicle to return to the garage.

ASC Teams are penalized if their snowplow vehicle requires a restart after their vehicle begins to plow snow from a snowfield path or if any part of their vehicle extends out of the Vehicle Starting, Maneuvering, or Plowed Snow Zones. ASC Teams will be assessed a **15% penalty** for each snowplow vehicle restart and a **15% penalty** for any snowfield Vehicle Starting, Maneuvering, or Plowed Snow Zone boundary infraction by the snowplow vehicle.

It is important that plowed snow be moved to areas that do not impede foot or vehicle traffic. Thus, ASC Teams are penalized for allowing any plowed snow to remain in the wrong zones along the competition snowfield. Snow must be plowed out of the Snow Path and moved into the Plowed Snow Zones, as marked on the snowfield diagrams. ASC Teams may use the Maneuvering and Vehicle Starting Zones to maneuver their vehicle or move snow between zones. If more than 50% of the snow plowed from the Snow Path remains in either the Maneuvering Zones or Vehicle Starting Zones at the end of their run, then ASC Teams are assessed a **10% penalty**.



Snowplow vehicles must maneuver to avoid both posts located within the competition snowfield. No part of the snowplow vehicle may strike a post during a run. Snow may fall up against a post without loss of points for hitting the post. However, any snow remaining on the Snow Path will reduce the overall score, and snow on the post will be considered as snow remaining on the Snow Path. If any part of a snowplow vehicle strikes a fixed points post, then a **15% penalty** will be assessed for that post.

Snowplow vehicles are required to park inside the Vehicle Starting Zone (Garage) at the end of their run. If any portion or all of the snowplow vehicle crosses the zone lines, the vehicle will be considered parked within the garage. Teams will be assessed a **20% penalty** if the snowplow vehicle fails to autonomously park inside the Vehicle Starting Zone at the end of the competition run. A Team may not declare a restart to gain the advantage of locating in the Vehicle Starting Zone at the end of their plowing run.

To encourage timely completion of the plowing the snowfield paths, ASC Teams can also earn extra points by completing each snowfield course in a time shorter than the allotted 20-minute competition time. Thus, ASC Teams could earn extra points for clearing a snowfield course in a timely manner. At least 50% of the snowfield path must be cleared to be eligible to earn these time related points.

For the Single Vehicle Event, the points awarded for the snow clearing performance will be scored using the following formula:

$$P_{SC} = FSC \left[ (0.85^{N_R})(0.85^{N_{BZ}})(0.9^{(1-D)})(0.85^{(1-M_1)})(0.85^{(1-M_2)})(0.8^{(1-G)}) + \frac{1}{10} \left( \frac{20 - t_{SC}}{20} \right) \right]$$

where,

$P_{SC}$	= points for snow clearing
$FSC$	= fraction of snow cleared from path as determined by judges
$N_R$	= number of full run restarts
$N_{BZ}$	= number of snowfield buffer zone boundary infractions
$D$	= drift snow remaining (= 1 if >50% plowed snow in Plowed Snow Zones, otherwise = 0)
$M_1$	= simulated fixed snow path post (= 1 if avoided, and = 0 if struck)
$M_2$	= simulated fixed snow zone post (= 1 if avoided, and = 0 if struck)
$G$	= garage parking (= 1 if successful, and = 0 if unsuccessful)
$t_{SC}$	= total snow clearing competition run time (rounded up to the next whole minute)

### **3.4 Awards and Prizes**

The ASC will award prizes to competition Teams in multiple categories. The amounts of the monetary awards are subject to change depending on the availability of sponsorship funds. The cash amount for each prize will be posted prior to the competition.

The ASC will award the prestigious Golden Shovel trophy and cash prize to the best Student Poster Presentation. ASC Teams will be considered for the Golden Shovel award based on the average of the total points accumulated from the ASC Judges after the review of the Presentations. The ASC Team with the highest accumulated score in this event will win the award.

The ASC will award the Dr. Nattu Golden Smile trophy and cash prize for the Team exhibiting the best sportsmanship throughout the competition. The ASC Committee will select a Team for this award based upon Team's participation, enthusiasm, and support of their own and other competitor's Team. This award is named in honor of Dr. Narasimhamurthi Natarajan (often called "Nattu" for short) from the University of Michigan, Dearborn, who led over ten competition Teams at the ASC, including three Teams in the 2014 ASC year, and led a number of Teams at the ION's past Robotic Lawnmower Competitions. Although Dr. Nattu passed away from a lung illness in 2016, his leadership and true camaraderie during the ASC event serves as the inspiration for this award.

The ASC will award cash prizes to the top ASC Teams at the conclusion of the event on Saturday. The cumulative total score of Presentations + Snow Path will determine the final standings for the Single Vehicle Event.

All trophies and prizes will be announced during the Awards Ceremony at the close of the ASC on Saturday afternoon of the competition week.

**To qualify for the total dollar prize amounts, a snowplow vehicle must plow at least 50% of the snowfield path during their competition run as scored by the ASC Judges.** If less than 50% of the snowfield path is plowed, then the ASC Team will only receive 50% of the total prize.

## 4 Appendix

### 4.2 Acronyms

The contents of Table 4 provide a list of commonly used acronyms for the ASC, including those used within this rulebook.

**Table 5. Autonomous Snowplow Competition Acronyms**

<b>ASC</b>	Autonomous Snowplow Competition
<b>ESS</b>	Emergency Stop System
<b>FQR</b>	Final Qualification Review
<b>GNSS</b>	Global Navigation Satellite System
<b>GPS</b>	Global Positioning System
<b>ION</b>	Institute of Navigation
<b>PDR</b>	Preliminary Design Review

### 4.3 Definitions

For the purposes of this competition, the following terms are defined as follows:

**Guidance:** The determination of the desired path or trajectory of travel from a vehicle's current position and velocity to a specified destination, including the necessary changes in vehicle velocity or attitude to follow the path.

**Navigation:** The determination at a specific instance in time of a vehicle's position, velocity, and attitude relative to a known reference frame.

**Control:** The manipulation of control surfaces, thrusters, or motors necessary to track the specific guidance commands, while maintaining vehicle stability, along the trajectory to a specified destination.

## 4.4 Obstacle Images

Images or diagrams of obstacles used within the ASC are provided in Figure 3. These obstacles include the fixed posts and the moving obstacle. These images are representative of the kind of obstacles that ASC Teams should expect, and these can be utilized for design and development of the snowplow vehicle and its navigation, guidance, and control system for obstacle avoidance.



Figure 3. Representative fixed post obstacles.

## 4.5 Final Qualification Review

The requirements set forth by the ACS are primarily designed for the safe operation of autonomous snowplow vehicles in the presence of people, animals, and property. Therefore, the FQR Vehicle Demonstration and Safety Inspection held on the day preceding the dynamic competition is focused on ensuring that each ASC snowplow vehicle meets the competition-related and safety-related requirements. Provided in Figure 4 is the checklist used by the ASC Judges during the FQR. ASC Teams are encouraged to review this checklist and verify their vehicle meets these requirements prior to FQR inspection.

**Final Qualification Review  
Vehicle Demonstration and Safety Inspection  
Checklist**

Team: \_\_\_\_\_

Category	Initial Inspection	Additional Inspection
<b>Snowplow Vehicle Physical Dimensions</b>		
Length: ≤ 2 m		
Width: ≤ 2 m		
Height: ≤ 2 m		
<b>Snowplow Vehicle: Tires</b>		
Tires: rubber; plastic or rubber augmentations		
<b>Snowplow Vehicle Speed Limit</b>		
Software review (printout): ≤ 2 m/s		
<b>Snowplow Vehicle Power &amp; Ground</b>		
Power Source: combustible fuel and/or batteries		
Electrical Ground		
<b>Snowplow Vehicle Safety: Physical Kill Switch</b>		
Color: red		
Diameter: ≥ 40 mm		
No protruding objects within 30 cm of Switch		
Vehicle Stop: ≤ 3 m from Switch activation		
No Single Point of Failure: demonstrate Switch routing to motor power cut-off		
<b>Snowplow Vehicle Safety: Wireless Kill Switch</b>		
Range: ≥ 50 m		
Vehicle stop: ≤ 3 m from Switch activation		
No Single Point of Failure: demonstrate Switch routing to motor power cut-off		
<b>Snowplow Vehicle Safety: Navigation Sensors</b>		
Sensors: lasers eye-safe (Class 1)		
Laser Harness: lasers safely mounted and secured		
Laser Boresight: points towards ground; angle at or below the local horizontal plane of device		
<b>Navigation Aiding Sources: Operation</b>		
Fluids or objects expelled by aiding source		
<b>Navigation Aiding Sources: Power &amp; Ground</b>		
Power Source: batteries		
Electrical Ground		
<b>Navigation Aiding Sources: Navigation Sensors</b>		
Sensors: lasers eye-safe (Class 1)		
Laser Harness: lasers safely mounted and secured		
Laser Boresight: points towards ground; angle at or below the local horizontal plane of device		
<b>Vehicle Operation</b>		
Autonomous Operation		
Fluids or objects expelled by vehicle		

**Figure 4. FQR Checklist.**